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SULPHUR DIOXIDE LEVELS
AND ENVIRONMENTAL STUDIES
IN THE WAWA AREA DURING 1971

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SUMMARY

A network of instruments to measure the ground-level concentrations of sulphur dioxide in the Wawa area was operated by the Air Quality Branch of the Ministry of the Environment during the 1971 growing season.

Sulphur dioxide was recorded at Goudreau 12.7% of the operative time, however, only 1.4% of these readings were over 0.25 ppm. In the town of Wawa, SO₂ was recorded 2.2% of the time and about 27% of these readings were over 0.25 ppm. In the Wawa area during the 1971 growing season, southwest winds accounted for 38% of the total. During periods of normal plant operations it would be expected that SO₂ would be recorded frequently at Goudreau which is approximately 21.6 miles northeast of the plant. The autometer in the town of Wawa is 1.5 miles southeast of the plant. Northwest winds accounted for the relatively low frequency of SO₂ fumigations in the town of Wawa.

Vegetation injury by SO₂ in the Wawa area was more common during 1971 than in the two previous seasons. Injury was most common in the area to the northeast of the sinter plant. At distances of up to about 15 miles practically all the major plant species were damaged to some extent. At greater distances, the injury was less severe and confined to species which are sensitive to SO₂.

In 1969, six surveillance plots and two control plots were established to monitor the effects of sulphur dioxide on the vegetation in the area to the northeast of the sinter plant. At each plot, 10 trees and 10 shrubs were tagged and the crown condition and insect, disease and SO₂ injury were recorded. Also two grids for the measurement of plant populations were set out adjacent to each plot. A lead peroxide candle was also located at each plot. These plots have been visited monthly during the growing season for the past three years.

Reduced SO₂ levels in the air northeast of the sinter plant in 1969 and 1970 have resulted in an improvement in the condition of the trees and the shrubs in the Fume Damage Area. Also there has been an increase in the herbaceous population of the ground flora. The return to full sinter production in 1971 may have an adverse effect on the vegetation during the forthcoming season.

The lead peroxide candle survey indicated that only background levels of SO₂ were found at the two control plots whereas elevated levels of SO₂ were recorded at the six surveillance plots with the highest sulphation rate at Plot 2, 10 miles northeast of the sinter plant. From Plot 2 to Plot 7 the sulphation rates decreased with increasing distance from the sinter plant.

In 1970 a program of sampling vegetation and soil for chemical analysis was initiated. For most plant species and soil, total sulphur,

sulphate-sulphur, and arsenic showed decreasing concentrations from Plot 2 to Plot 7, while the values for fluoride, iron, and zinc failed to show any definite pattern.

This program will be continued in 1972 to closely follow the effects of the sinter plant on the vegetation in the sector northeast of Wawa.

I Sulphur Dioxide Levels in the Wawa Area During 1971

The Air Quality Branch, Ontario Ministry of the Environment continued to monitor the SO₂ in the Wawa area during the 1971 growing season (June-September). The monitoring program was originally set-up in 1961 to measure the SO₂ emissions of the Algoma Ore Division; The Algoma Steel Corporation Limited at Wawa. Since 1961 the program has been continued with minor modifications.

Two Thomas autometers and eight lead peroxide candles were operated in the Wawa area during 1971. One autometer was located at Goudreau 21.6 miles northeast of Wawa and the other in the town of Wawa. The lead peroxide candles were exposed adjacent to the eight vegetation study plots which were set-up in 1969 by the Phytotoxicology Section, Air Quality Branch and the Department of Lands and Forests. The locations of the autometers, candles, and vegetation plots are shown in Fig. 1.

In 1961 the Algoma Ore Division initiated a program whereby selected low sulphur content ore was sintered during the growing season and the higher sulphur content ore was used during the non-growing season. Table 1 and Figs. 2&3 show the results of the program over the years. In 1971, 32,723 gross tons of sulphur were emitted to the atmosphere as SO₂ in the period between May 12th and September 30. Only in 1961 was a greater amount of SO₂ given off during a growing season. The marked change in the production and emissions between 1971 and the previous two seasons is due to the fact that the plant was shut down for lengthy periods during 1969 and 1970. Sinter production in 1971 totalled more than 650,000 gross tons, the highest since 1961.

(a) Sulphur dioxide levels recorded in the town of Wawa - 1971

One Thomas autometer was operated at 29 Hillcrest Ave., Wawa from June 7th to October 20th, 1971. During this period valid sulphur dioxide data was collected for 88% of the time. The SO₂ levels recorded at this location for the 1971, as well as the 1969 and 1970, seasons are shown in table 2.

Sulphur dioxide was recorded at Wawa during the daylight hours on six days during June. On June 12th, a 5½ hour fumigation occurred which had a maximum half-hour concentration of 1.73 ppm. The intensity of this fumigation was 175, almost twice the level which is generally considered to be harmful to vegetation. The intensity factor of a fumigation is calculated by combining the concentration and duration of the fumigation. A concentration of 0.95 ppm for 1 hr., 0.55 ppm for 2 hrs., 0.35 ppm for 4 hrs. or 0.25 ppm for 8 hrs., would equal an intensity factor of 100. Another fumigation occurred on June 24th, and it had an intensity of 67. The other four fumigations which occurred during the month had intensities of less than 10.

During July, SO₂ was recorded at Wawa on seven days. The maximum half-hour concentration was 0.72 ppm and this occurred during a fumigation on July 22nd which had an intensity of 62. The intensities of the other six fumigations which occurred during the month were well below the level which is generally considered to be harmful to vegetation.

Eight fumigations were recorded at Wawa during the daylight hours during the month of August 1971. The average intensity of the eight fumigations was only 14, however one fumigation did have an intensity of 96.

Sulphur dioxide was recorded during two days at Wawa in September. This is rather misleading since the autometer was inoperative for a period of time at the first of the month and it is probable that more fumigations occurred than are reported. The fumigation with the highest intensity ever recorded in the Wawa area occurred on September 23rd. The intensity of this five hour fumigation was 268, almost three times the level which is considered to be harmful to vegetation. The maximum half-hour concentration of this fumigation was 1.84 ppm. Residents of the area near the autometer complained of high levels of SO₂ on the afternoon of September 23rd.

The autometer at Wawa was closed down for the season on October 20th. Sulphur dioxide was recorded on five of the operative days. The maximum half-hour concentration was 1.06 ppm and this occurred on October 7th. The intensity of this fumigation was 81. The average intensity of the other four fumigations was about 40.

(b) Sulphur dioxide levels recorded at Goudreau - 1971

A Thomas autometer was operated at Goudreau, 21.6 miles northeast of Wawa, from June 10th to October 14th, 1971. Valid SO₂ data was collected for about 75% of this period. Valid SO₂ data was collected for over 95% of the time during June, July, and August, the months in which vegetation injury by SO₂ has been most common in the Wawa area during previous years. Lengthy inoperative periods in September and October were encountered as a result of mechanical breakdowns and power failures.

Sulphur dioxide was recorded at Goudreau on 11 days in June (Table 3). A maximum half-hour concentration of 0.28 ppm occurred on June 29th. The maximum intensity, 54, also occurred on June 29th.

During July winds in the Wawa area were out of the southwest 57.5% of the time (table 4). The mean for the eight-year period 1962-1969 indicated that in previous years southwest winds in July usually occurred about 30% of the time. The abnormally high frequency of southwest winds resulted in a correspondingly high frequency of SO₂ fumigations at Goudreau. Sulphur dioxide was recorded on 22 days

during July. Although SO₂ was recorded 23.9% of the time during July (Table 3), the concentrations were relatively low with only 0.1% of the readings above 0.25 ppm.

In August, southwest winds accounted for only about 38% of the total and as would be expected there was a decrease in the incidence of SO₂ fumigations at Goudreau. Sulphur dioxide was recorded on 17 days during the month. The maximum half-hour concentration, 0.48 ppm, occurred on August 18th. The intensities of the 17 fumigations ranged from 1 to 48.

The autometer at Goudreau was inoperative for an abnormally long period of time in September and the data presented for the month is probably not truly representative of the entire month. Sulphur dioxide was recorded on seven days during the month and all the half-hour concentration readings were below 0.25 ppm.

The SO₂ monitor at Goudreau was operated for only the first 14 days of October. Sulphur dioxide was recorded on five of these days. The maximum intensity during the month was only 13 (Table 5). Table 6 shows the maximum intensities recorded at Goudreau during the month of June, July, August and September for the period 1961 to 1971.

II Sulphur Dioxide Injury to Vegetation during 1971

Vegetation was injured on several occasions in the Wawa area during the 1971 growing season. The incidence of severe injury was less common than in most of the previous seasons, excluding 1969 and 1970 when the sinter plant was shut down for part of the growing season. However, trace injury did occur, particularly on the sensitive plant species, over most of the Wawa "Fume Damage Area".

In the town of Wawa, trace injury (1-5% of leaf area damaged) occurred on white birch and trembling aspen in early July. The injury was confined to trees in the northeast section of the town. In late August or early September trace injury occurred on white birch again in this section of the town. Only two potentially injurious fumigations were recorded at the autometer station in Wawa during 1971. One occurred on June 12th with an intensity of 175, and the other on September 23rd with an intensity of 268. If either of these fumigations had occurred in July or in August when the vegetation was growing vigorously, injury would probably have been much more common and severe.

In the area around Parks Lake and Finger Lake (approximately 12 miles northeast of Wawa) severe injury (over 35% of leaf area damaged) was common in July, August, and September on white birch and

trembling aspen. Moderate injury (16-35% of leaf area damaged) in June occurred on these species. Light injury (6-15% of leaf area damaged) was observed on mountain maple, pin cherry, showy mountain ash, and dogwood. Ground cover vegetation such as strawberry, raspberry, bracken fern, and fireweed received trace to light injury in July and August. Injury by SO₂ has been reported in this area each year since 1961. In 1969, the Phytotoxicology Section of the Air Quality Branch in co-operation with the Ontario Department of Lands and Forests established two vegetation study plots in this area. The plots were set-up to study the vegetation and soil in this region in a more detailed manner than had been done in previous years (Plot nos. 2 and 3).

Vegetation in the area around Perry Lake and Garbe Lake (approximately 18 miles northeast of Wawa) was also injured by SO₂ during July, August and September. In July, trace injury occurred on only white birch and trembling aspen. During August, trace to severe injury occurred on white birch and trembling aspen, whereas, light injury occurred on jack pine, hazel, showy mountain ash, and raspberry. Species such as balsam fir and white cedar which are generally considered to be resistant to SO₂ were not injured in this area during 1971. Two vegetation study plots were located in this area (Plot nos. 4 and 5).

At Goudreau and at Herman Lake (approximately 23 miles northeast of Wawa) white birch, trembling aspen, and pin cherry were damaged in trace amounts during August and September. In 1969 a vegetation study plot was established at each of these locations (Plot nos. 6 and 7).

With the exception of the 1969 and 1970 seasons injury to vegetation by sulphur dioxide in the Wawa area over the past decade has occurred in about the same general area. Vegetation to the northeast of the sinter plant has been affected to the greatest extent. Severe injury on almost all major species of vegetation has occurred at distances of up to 15 miles from the plant. At greater distances, injury has been less severe and usually confined to those species of vegetation which are sensitive to SO₂. The high frequency of south-west winds during the summer, and the local topography have resulted in frequent fumigations in the area to the northeast.

III Wawa Area Vegetation Study Plots

In 1969, the Phytotoxicology Section of the Air Quality Branch in co-operation with the White River District of the Department of Lands and Forests established six surveillance plots in a transect line northeast of the sinter plant and two control plots located outside the Fume Damage Area (35 miles from the sinter plant) as follows:

Plot #1 Location: Control plot located outside the Fume Damage area in Obatanga Provincial Park, 35 miles northwest of the sinter plant.

Site Description: Mixed habitat; spruce and fir canopy, boggy area, lake edge; abundant soil moisture, rich humus layer; canopy recently opened by wind throw.

Plot #2 Location: Parks Lake located in the "Total Kill" section of the Fume Damage area 10 miles northeast of the sinter plant.

Site Description: Open, low shrubby area, few (20') trees; rocky outcrops, soil thin, vegetation sparse in exposed sites, dense in protected, damp sites; many grassy or "weedy" glades.

Plot #3 Location: Finger Lake located in the "Total Kill" section of the Fume Damage area 12 miles northeast of the sinter plant.

Site Description: Low trees and shrubs canopy; shrubs dense; rocky outcrops, soil thin, little humus; similar to Plot #2.

Plot #4 Location: Perry Lake located in the "Heavy Kill" section of the Fume Damage area 16 miles northeast of the sinter plant

Site Description: Dense spruce, fir canopy, trees 30' tall, thick humus layer, few rock outcrops, many seedlings.

Plot #5 Location: Garbe Lake located in the "Heavy Kill" section of the Fume Damage area, 19 miles northeast of the sinter plant.

Site Description: Open spruce-birch canopy; thin humus, medium to dry soil, many rocky outcrops.

Plot #6 Location: Goudreau townsite located in the "Light Damage" section of the Fume Damage area, 22 miles northeast of the sinter plant.

Site Description: Dry open woods with aspen predominating on a south slope, disturbed site, many "weedy" species.

Plot #7 Location: Herman Lake located in the "Light Damage" section of the Fume Damage area, 24 miles northeast of the sinter plant.

Site Description: Small island, disturbed by habitation; white birch dominating, open, low shrub cover; many "weedy" species, gravelly lake shore.

Plot #8 Location: Control plot located outside the Fume Damage area near Crouche Lake, 38 miles northeast of the sinter plant.

Site Description: 20° slope with a southern exposure; soil thin, dry; abundant litter; canopy open; trembling aspen and maple dominant.

(see Fig. 1 for plot locations)

Note: The terms, Fume Damage area; Total Kill; Heavy Kill; and Light Damage, refer to the designations assigned to the various areas by the Department of Lands and Forests during their aerial surveys of the region to assess the impact of the sinter plant fumes on white birch in the area.

When the surveillance plots were established in 1969, 10 trees (trembling aspen and/or white birch) and 10 shrubs (showy mountain ash, mountain maple, prairie willow, red osier dogwood, elderberry, pin cherry, speckled alder, beaked hazel, or serviceberry) were tagged in a 66 ft. x 66 ft. area at each plot. The "crown condition" of the trees was recorded along with insect, disease, or sulphur dioxide injury in order to establish a history of the vegetation on the plots.

At each plot two 3.3 ft. x 3.3 ft. grids were established and the number and species of each type of plant found on these grids were recorded to determine any differences in populations with distance from the sinter plant and any future fluctuations in plant populations.

A program of sampling the vegetation and soil for chemical analysis was also initiated in 1970. Leaf samples from trembling aspen, white birch, mountain maple (or substitute); forage; and soil, were collected from each of the plots in June, July, August, and September and analysed for fluoride, total sulphur, sulphate-sulphur, arsenic, iron, and zinc.

All facets of this program were continued during the 1971 growing season.

Observations

(a) Tree Crown Condition

The "crown condition" classification system employed was one developed by the Canadian Forestry Service for hardwood species in Ontario. A classification gradation from 1A (healthy) to 6B (dead), with several intermediate conditions, allowed for an informative description of the crown condition at the time of surveillance.

Table 7 shows the changes in the crown conditions from 1969 to 1970 and from 1970 to 1971 at each of the eight vegetation plots in the Wawa area.

The overall picture appears to be one of improvement, especially during this past growing season. There has been a shift from declining crowns to improved or maintained positions. Plot #2 (Parks Lake, 10 miles northeast of the sinter plant) is the exception to this general trend. The trees and shrubs on this plot have been damaged for several years in succession by high intensity fumigations and it is unlikely that much improvement will be seen at this location. To date one tree of the twenty tagged specimens has died and six are declining while only nine trees or shrubs are maintaining their present condition.

The general improvement in the crown conditions in the Fume Damage area is no doubt due to the fact that during 1969 the sinter plant was shut down from August 2nd till November 10th and during 1970 from July 4th till August 3rd. The result of these shutdowns and the use of low sulphur-content ore was a reduced amount of atmospheric sulphur dioxide in this area in 1969 and 1970. However, during 1971 there was no shutdown period and the number of gross tons of sulphur lost as sulphur dioxide was almost double that of each of the previous two years. Therefore this may jeopardize the trend of improvement and, close surveillance of this area will be maintained in 1972 to discern the effect of this return to increased production on the crown conditions of the trees and shrubs presently under study.

(b) Plant Population Studies

The recording of the vegetation populations in the two grids established adjacent to each of the eight Wawa plots has been in progress for three growing seasons (1969, 1970, 1971). A minimum of five years data is required before meaningful statistical analysis can be applied to the results in this type of study. However, a preliminary review of the information gathered to date reveals the possible indication of meaningful trends. Table 8 shows the number of species of trees, shrubs, and herbaceous plants present in the grids in 1969, 1970, and 1971. It also shows the number of individuals for these plant-types. Some plants are more easily tallied as clumps or patches (taking area covered into consideration) and these have also been listed in addition to the number of individuals. Mosses, grasses, and sedges etc. have not always been species-identified, therefore, only the number of clumps or patches of this group has been listed for each year. The following points show the general trends observed for the plant populations present in these grids:

- (1) The number of species and the number of individuals on the control grids do not fluctuate to any great degree, although the number of trees does decline at Plots 1 and 8.
- (2) In nearly all instances the number of species of trees, shrubs and herbaceous plants remains the same or increases in the grids near the six surveillance plots in the Fume Damage Area.
- (3) As in the control grids, the number of trees has declined in the grids near the six surveillance plots since 1969. Since most of the trees tallied in this study were seedlings, this represents a decrease in forest regeneration.
- (4) The number of species of shrubs and the number of individuals or clumps in the grids in the Fume Damage area are not fluctuating in any definite pattern.
- (5) The grass, sedge, moss, lichen populations are relatively steady in all grids.
- (6) The most significant trend is the increase in the number of species and the number of individuals of herbaceous plants from 1969 to 1970 and their maintenance at this higher level in 1971, especially in Plots 2,3,5, and 6.

(c) Lead Peroxide Candle Survey

In 1961, the Ontario Department of Mines initiated a lead peroxide candle survey for the measurement of sulphur dioxide in the Wawa area. This program was sustained by the responsible Departments until 1970. In 1970 the locations of the lead peroxide candles were altered to coincide with the vegetation plots. The distances between some of the old candle locations and the vegetation plots were not great and therefore part of the previous data is comparable with that gained for the 1970 and 1971 seasons at the new locations. Table 9 shows the mean values (mgm SO₂/100 cm²/day) for the period from 1961 to 1970 (not including 1969, since the sinter plant was shutdown for a lengthy period) for the original stations located northeast of Wawa. The following previous locations are relatively close to the new surveillance plots.

Goetz Lake, 10 m. NE
(also called Parks Lake)

Parks Lake, 10 m. NE
Plot #2

Magpie River, 14 m. NE

Finger Lake, 12 m. NE
Plot #3

Goudreau, 21.6 m. NE

Goudreau, 22 m. NE
Plot #6

Herman Lake, 24 m. NE

Herman Lake, 24 m. NE
Plot #7

Cawdron Lake, 30 m. NE
Localsh 34 m. NE

Crouche Lake, 38 m. NE
Plot #8

Tables 10 & 11 show the sulphation rate results for 1970 and 1971 respectively for the candles which were exposed at the vegetation plots. When Tables 9, 10 & 11 are examined together there is a good correlation between the results from Goetz Lake and Parks Lake, Magpie River and Finger Lake, and the two locations at both Goudreau and Herman Lake. However the values for Cawdron Lake (30 m. NE) and Localsh (34 m. NE) are still considerably higher than those obtained for Crouche Lake (38 m. NE) which is one of the new control plots.

In all three tables the sulphation values decrease with increasing distance from the source as would be expected. The results for 1970 for Plots 2 and 3 (1.03 and .61 mgm SO₃/100 cm²/day respectively) are lower than those for 1971 for the same Plots (1.47 and .88 mgm SO₃/100 cm²/day). This is a reflection of the increased production during the 1971 growing season. Between Plots 4 and 7 the SO₂ gas becomes dispersed and the levels range from .20 to .55 mgm SO₃/100 cm²/day. At the control plots 35 miles northwest and 38 miles northeast of the sinter plant only background levels of SO₂ were recorded.

IV Results of Chemical Analysis of 1970 Vegetation and Soil Samples

The full chemical analysis of the samples collected in 1971 is still in progress at the time of writing this report. However, the 1970 data have been compiled and subjected to statistical analysis. Table 12 shows the average concentrations (for four collections; June, July, August, and September) of each of the elements in each of the species and in the soil sampled at the eight study plots. An analysis of variance (Table 13) shows that for all elements except fluoride, the differences between the species were significant at the 1% level. This is the expected result since the leaves of one species would contain greater or smaller amounts of a given element than those of another species. The table of analysis of variance also shows that for total sulphur, sulphate-sulphur, arsenic, iron, and zinc, the levels of those elements in the vegetation are significantly different from station to station. This statistical relationship is the result of the fact that several elements in several plant species show declining concentrations in the foliage with increased distance from the source from Plot 2 to Plot 7 as follows:

<u>Species</u>	<u>Elements</u>
Trembling aspen	SO ₄ -S, As, Zn
White Birch	ToS, SO ₄ -S, As
Mountain Maple	F, SO ₄ -S, Fe, As
Showy Mountain Ash	ToS, SO ₄ -S, As
Forage	As

This trend was also apparent in the soil for total sulphur, sulphate-sulphur, and arsenic.

The table above illustrates that total sulphur, sulphate-sulphur and arsenic are the most common elements to follow this trend while fluoride, iron, and zinc rarely exhibit this trait. To find the correlation between the concentration of the various elements in the vegetation and the distance from the sinter plant, the mean values for all of the vegetation (all species) collected at each plot were calculated along with the standard error for the six elements. When these means were plotted against the distance from the sinter plant the regression equations and the correlation coefficients were obtained. Table 14 shows that for total sulphur, sulphate-sulphur, and arsenic there is a significant (5% level) relationship between the amounts of these elements in the vegetation and their distance from the source. At the same time, fluoride, iron, and zinc are not related to distance in this manner. Since the fluoride levels in the vegetation and soil were within the normal range, fluoride analysis was discontinued in the 1971 program. The inconsistent data for iron and zinc may be due to local geological conditions or the differing rates of absorption by the various species.

Plots 2 and 3 (10 and 12 miles northeast of the sinter plant) are the two stations which show the highest levels of contamination in vegetation and soil. This is also the region where sulphur dioxide injury to vegetation is greatest and the lead peroxide candle readings are the highest.

V Correlation Between the Sulphur Levels in the Vegetation and the Sulphation Rate on the Lead Peroxide Candles

The mean values described above for total sulphur and sulphate-sulphur for all of the vegetation collected at each plot were plotted against the sulphation rates for the lead peroxide candles. From the resulting straight-line relationships (Figs. 4 and 5) the regression equations were calculated and the correlation coefficients were obtained (Table 15). The relationship between total sulphur in the vegetation and the candle sulphation rate was significant at the 5% level ($r = 0.84$), whereas the relationship

between the vegetation sulphate-sulphur levels and the candle sulphation rate was significant at the 1% level ($r = 0.97$), where r is the correlation coefficient.

These close correlations confirm earlier statements that the higher incidence of injury, especially at Plots 2 and 3 is the result of sulphur dioxide fumigations and that the high levels of sulphur in the vegetation are related to increased concentrations of sulphur dioxide in the ambient air.

Vegetation sampling and air monitoring will be continued through the 1972 growing season and a close surveillance of the forest communities will be maintained to determine the effects of the sinter plant operation on the environment in the Wawa area.

VI. Acknowledgments

The authors wish to express their appreciation to Dr. S. N. Iinzon, Chief of the Phytotoxicology Section, Air Quality Branch for his advice and supervision; to Mr. D. Ogner for compiling the SO₂ data; to Mr. H. Griffin and the staff of the Department of Lands and Forests at Wawa for arranging transportation and assisting in the sampling; to Messrs A. W. Hill and P. J. Temple for assistance given in examining the Wawa area vegetation; to Mr. A. C. Rayner and his staff for analysis of samples; to Mr. R. Chai for statistical analysis of data; to Dr. J. Standidge of the Algoma Ore Corporation for furnishing production and meteorological data; and to Mrs. J. Springer for secretarial assistance. The contributions and cooperation of these people made possible the presentation of this report.

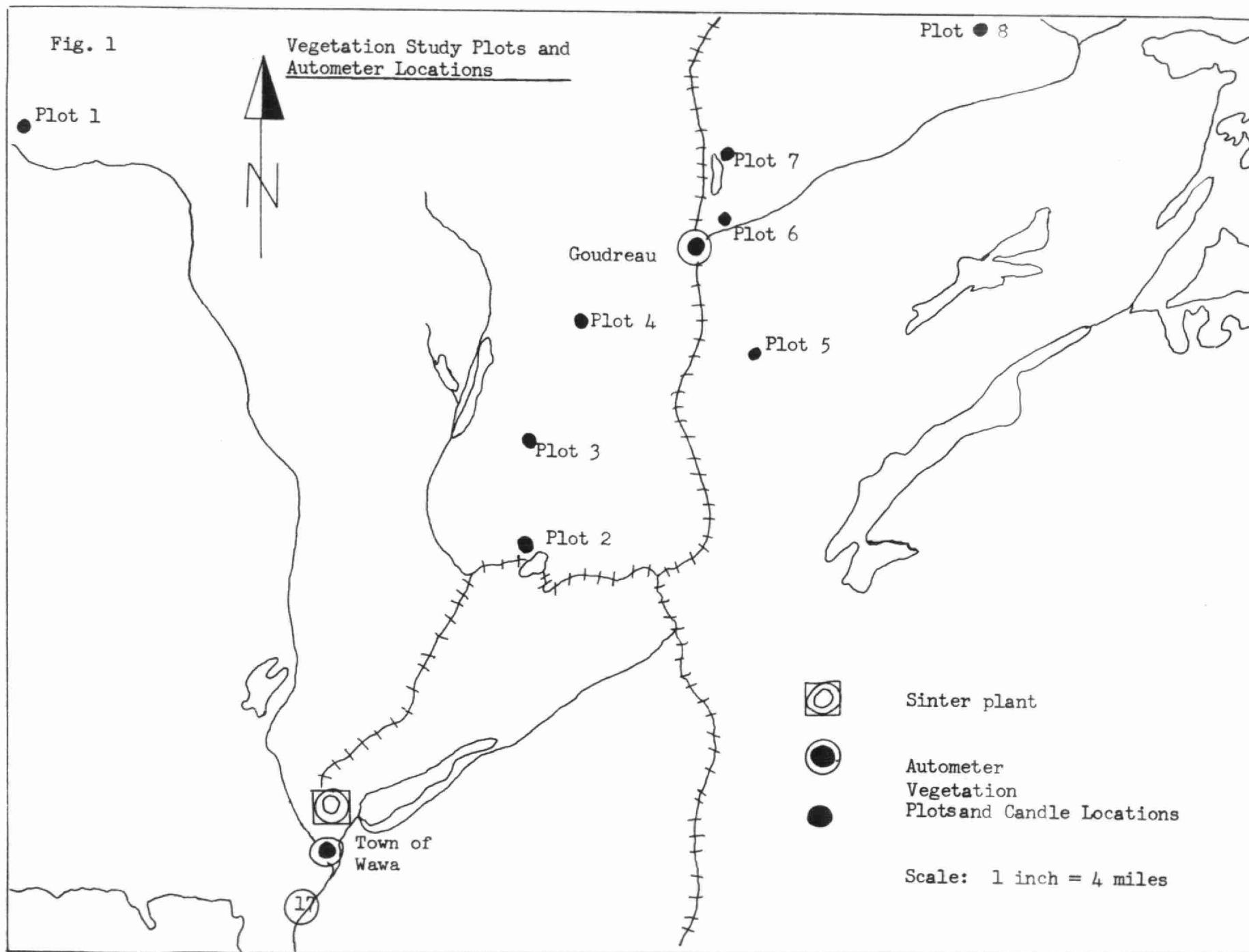


Fig. 2

Relationship between Ore Feed and Sulphur Content of Ore 1961-1971

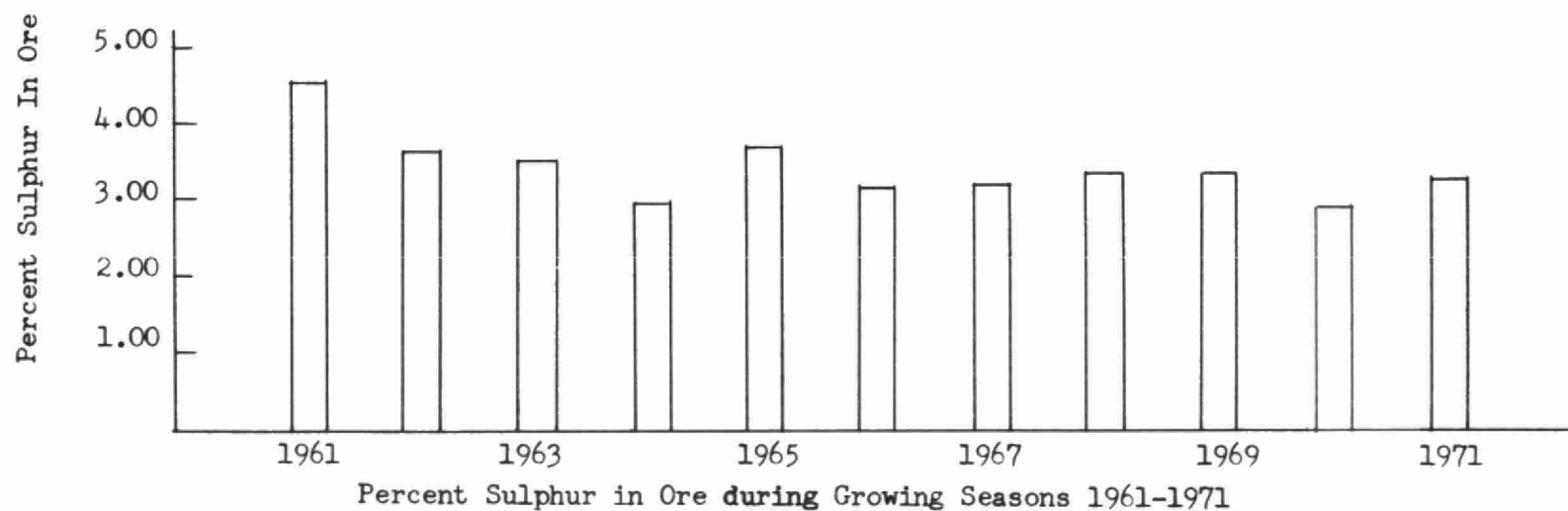
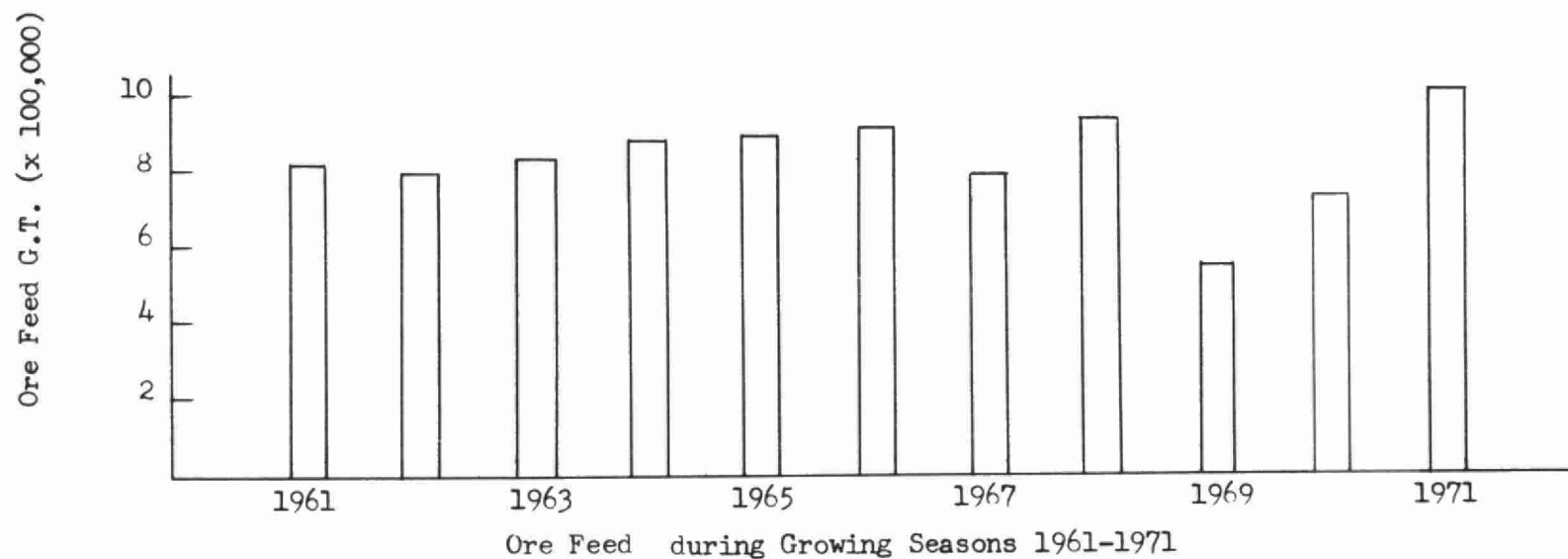
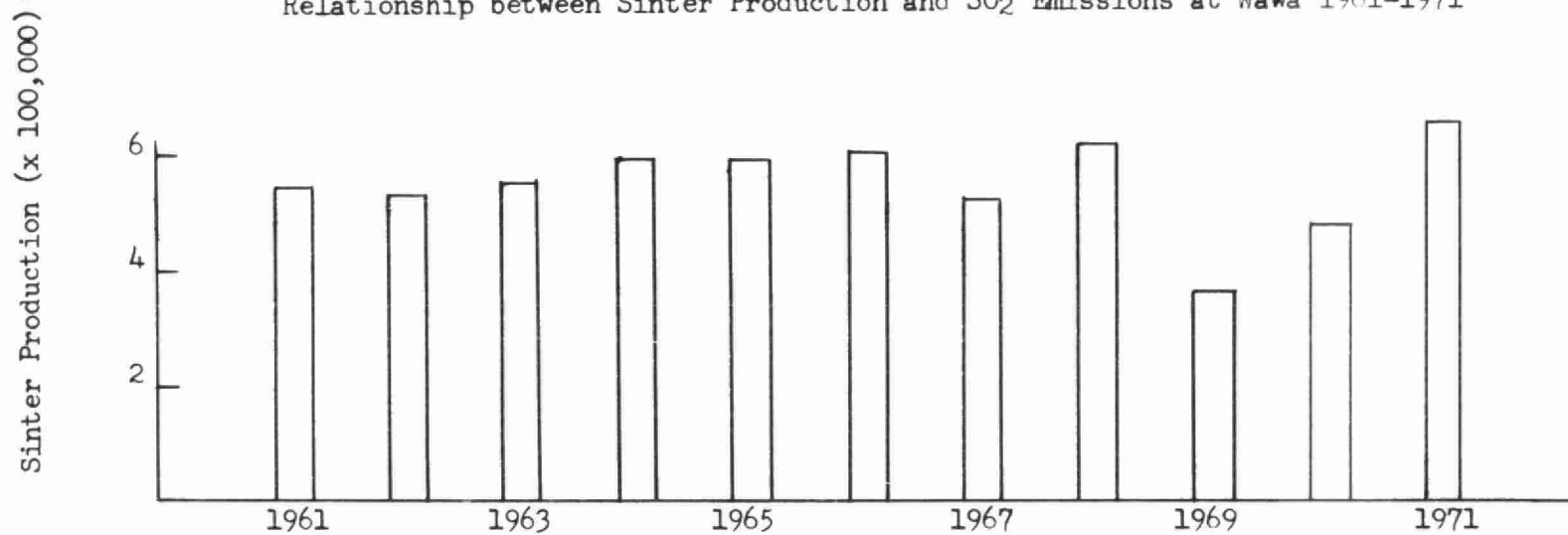


Fig. 3

Relationship between Sinter Production and SO₂ Emissions at Wawa 1961-1971



Sinter Production during Growing Seasons 1961-1971

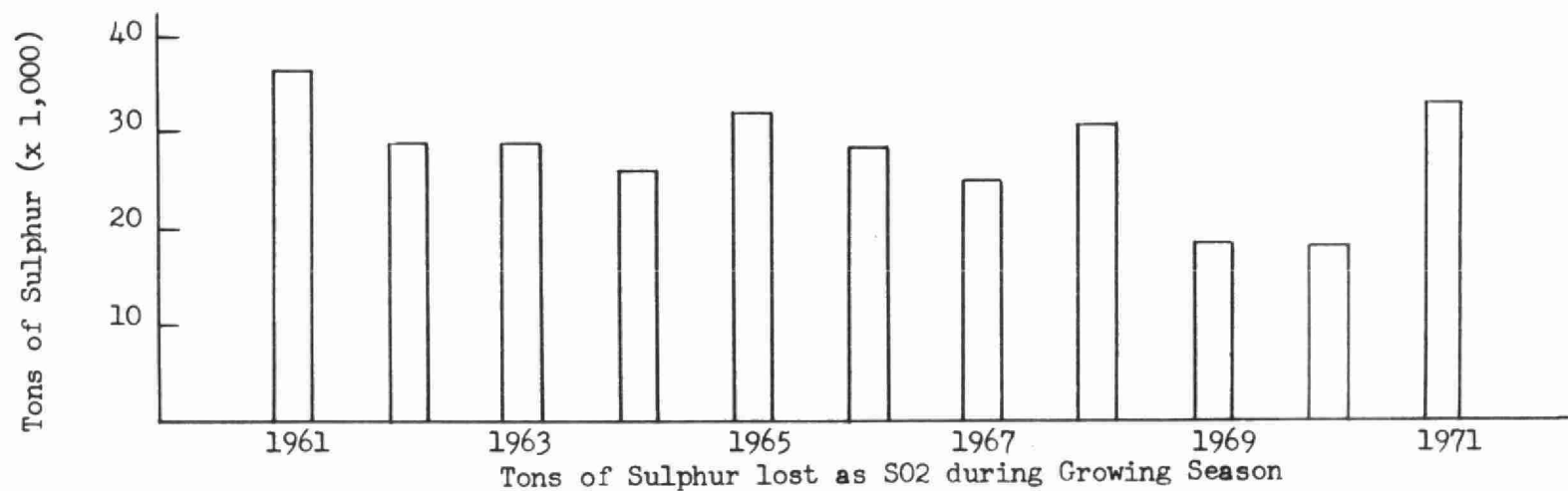


Fig. 4

Relationship between the air candle sulphation rate
and Total Sulphur (%) in Vegetation Samples
Wawa area 1970

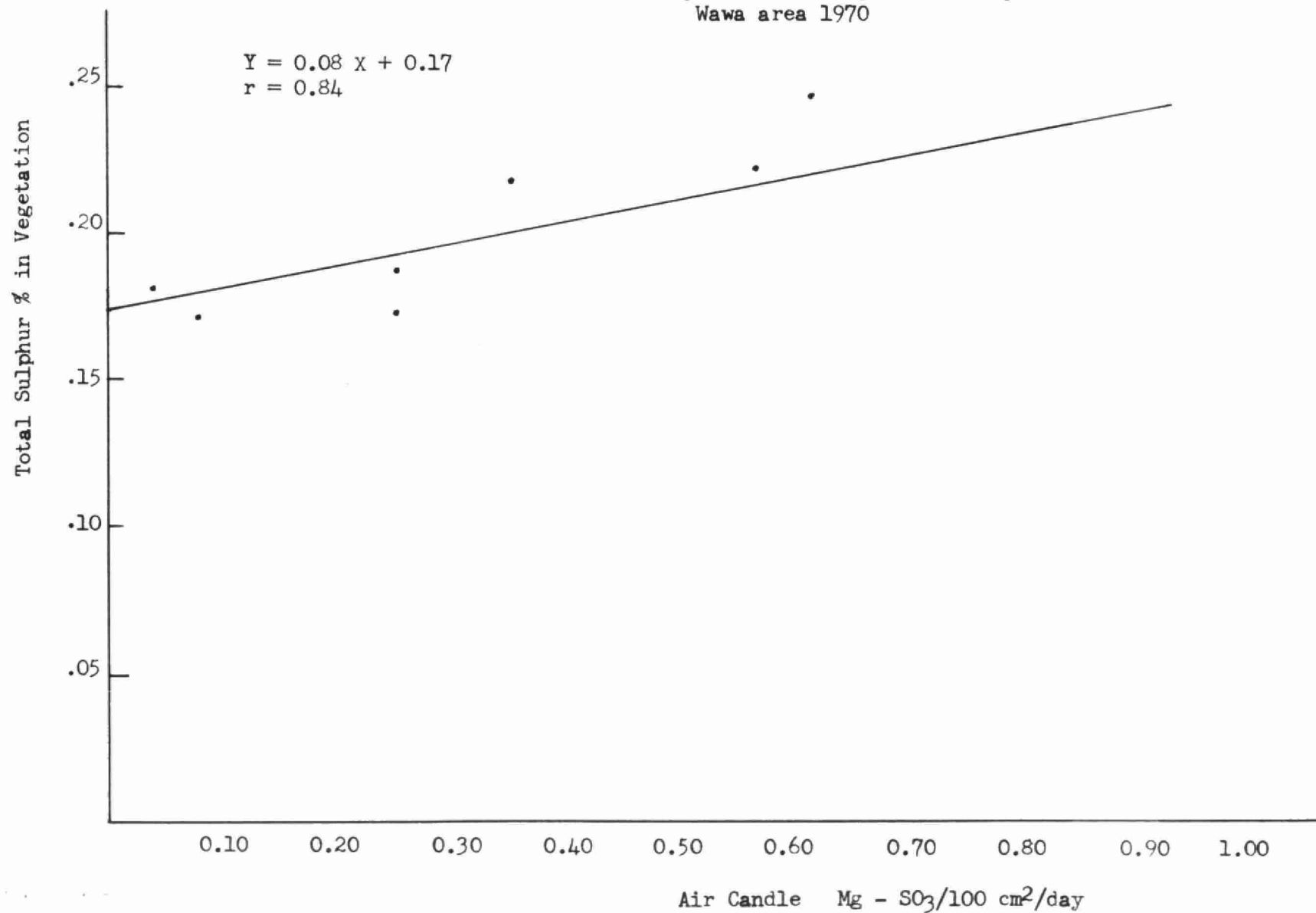


Fig. 5

Relationship between the air candle sulphation rate
and $\text{SO}_4\text{-S}(\%)$ in vegetation samples
Wawa area 1970

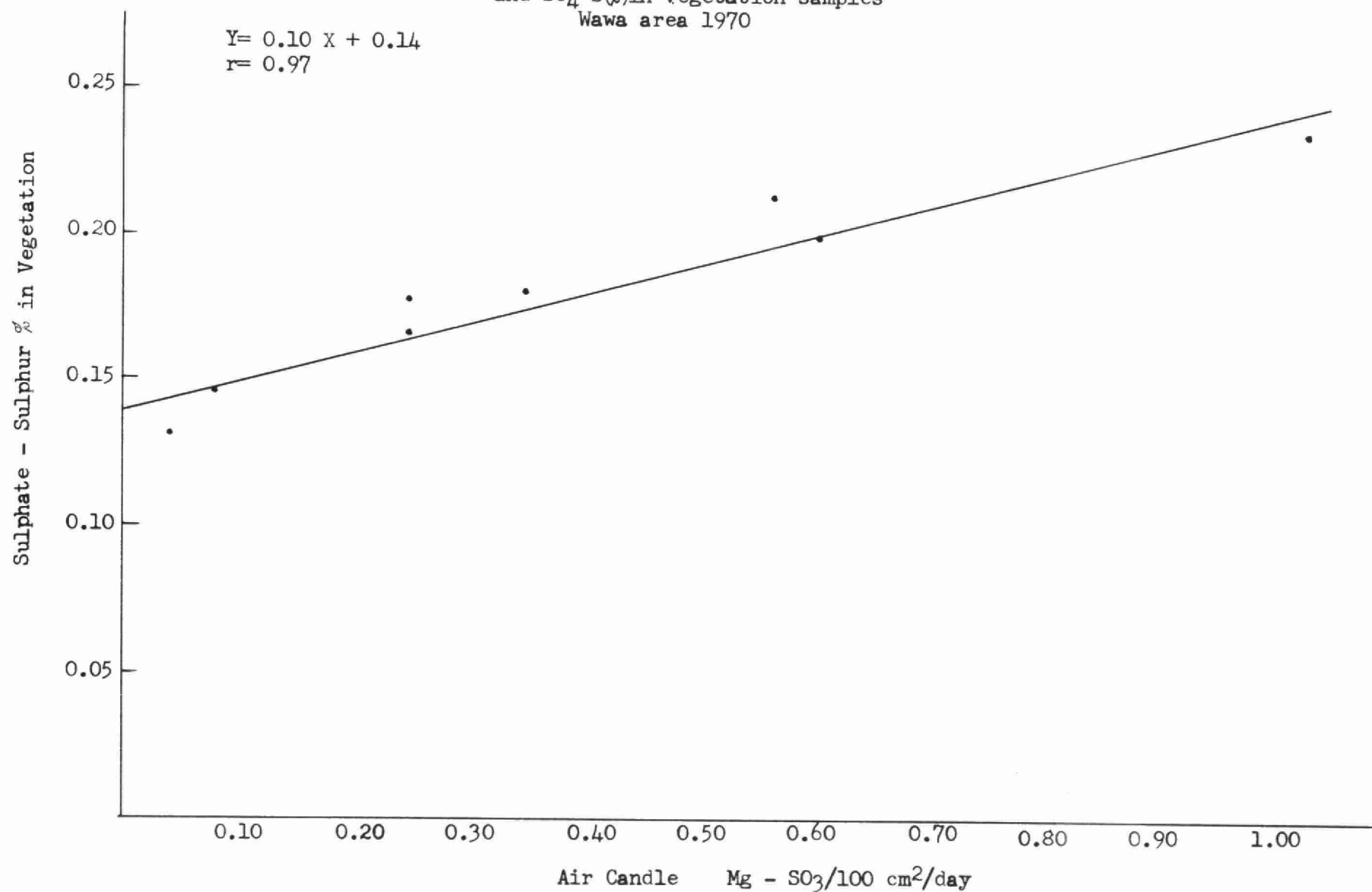


Table 1

Production and Emissions at Wawa during 1961-1971 Growing Seasons

Year	Ore Feed (G.T.)	% Sulphur In Ore	Sinter Produced From Ore (G.T.)	Sulphur Lost As SO ₂ (G.T.)
1961	816,311	4.55	575,825	36,479
1962	800,697	3.66	540,700	28,657
1963	832,069	3.53	545,445	28,837
1964	893,990	3.00	562,637	26,087
1965	891,818	3.70	620,249	32,194
1966	923,785	3.19	628,930	28,790
1967	794,128	3.24	543,377	25,223
1968	926,734	3.38	609,406	30,822
1969	554,339	3.39	364,554	18,479
1970	733,630	3.00	434,726	18,069
1971	1,002,012	3.35	654,892	32,723

Table 2

Summary of Sulphur Dioxide data recorded in the town of Wawa during 1969, 1970, 1971

Year	Total sampling Time (hrs.)	Zero readings		SO2 readings		Max. $\frac{1}{2}$ hour conc. (ppm)	Average ppm for	
		hrs.	%	hrs.	%		SO2 periods only	Total period
----- June -----								
1969	152.0	150.0	98.7	2.0	1.3	0.35	.17	.01
1970	651.0	634.5	97.4	16.5	2.5	0.48	.09	.01
1971	537.0	524.0	97.5	13.0	2.4	1.73	.26	.01
----- July -----								
1969	744.0	726.0	97.6	18.0	2.4	0.14	.05	.01
1970	744.0	740.5	99.6	3.5	0.4	0.10	.06	.01
1971	743.0	727.0	97.8	16.0	2.1	0.72	.10	.01
----- August -----								
1969	744.0	744.0	100.0	0.0	0.0	0.00	.00	.00
1970	744.0	728.0	97.8	16.0	2.2	1.22	.25	.01
1971	725.0	712.5	98.2	12.5	1.7	0.63	.20	.01
----- September -----								
1969	744.0	744.0	100.0	0.0	0.0	0.00	.00	.00
1970	720.0	702.5	97.6	17.5	2.4	0.38	.12	.01
1971	183.0	175.5	95.9	7.5	4.0	1.84	.51	.02
----- October -----								
1969	512.5	512.5	100.0	0.0	0.0	0.00	.00	.00
1970	488.0	462.0	94.7	26.0	5.3	0.78	.15	.01
1971	471.5	461.5	97.8	10.0	2.0	1.06	.22	.01
----- Season -----								
1969	2872.5	2852.5	99.3	20.0	0.7	0.35	.06	.01
1970	3618.5	3531.0	97.6	87.5	2.4	1.22	.16	.01
1971	2658.5	2600.5	97.8	59.0	0.2	1.84	.23	.01

Table 3

Summary of sulphur dioxide data recorded at Goudreau, Ont. 1961-1971

Year	S lost as SO ₂ 1000 tons	Total sampling time (hrs.)	Zero readings		SO ₂ readings		Half-hour concs. above				Max. ppm $\frac{1}{2}$ -hr.	Av. ppm for	
			hrs.	%	hrs.	%	.25 ppm		.50 ppm			SO ₂ periods only	Total period
							hrs.	%	hrs.	%			
-May-													
1961		-	-	-	-	-	-	-	-	-	-	-	-
1962		170.5	159.0	93.0	11.5	6.7	0.0	0.0	0.0	0.0	.17	.054	.004
1963		15.0	9.5	63.3	5.5	36.7	0.0	0.0	0.0	0.0	.05	.020	.007
1964		96.5	83.5	86.5	13.0	13.5	1.0	1.0	0.0	0.0	.27	.074	.010
1965		119.5	71.5	59.8	48.0	40.2	2.5	2.1	0.0	0.0	.46	.087	.035
1966		142.0	137.5	96.8	4.5	3.2	0.0	0.0	0.0	0.0	.08	.034	.001
1967		297.0	284.5	95.8	12.5	4.2	1.0	0.3	0.0	0.0	.33	.072	.003
1968		365.5	326.0	89.2	39.5	10.8	4.0	1.1	0.5	0.1	.54	.080	.009
1969		80.5	66.0	82.0	14.5	18.0	0.0	0.0	0.0	0.0	.20	.047	.008
1970		158.0	150.0	94.9	8.0	5.1	0.0	0.0	0.0	0.0	.10	.036	.002
1971		-	-	-	-	-	-	-	-	-	-	-	-
-June-													
1961	10.2	357.0	247.5	69.3	109.5	30.7	6.5	1.8	0.0	0.0	.46	.107	.033
1962	6.8	586.5	430.0	73.3	151.5	26.7	3.0	0.5	0.0	0.0	.33	.076	.020
1963	6.7	553.0	401.5	72.6	151.5	27.4	0.0	0.0	0.0	0.0	.24	.041	.011
1964	7.8	640.5	463.5	72.4	177.0	27.6	8.5	1.3	1.5	0.2	.61	.078	.022
1965	8.8	668.5	514.4	77.0	154.0	23.0	4.5	0.7	1.0	0.2	.60	.078	.018
1966	7.4	720.0	491.0	68.2	229.0	31.8	7.0	1.0	0.0	0.0	.47	.072	.023
1967	5.9	698.5	477.0	68.3	221.5	31.7	5.0	0.7	0.0	0.0	.35	.065	.021
1968	8.3	657.5	493.5	75.1	164.0	24.9	3.5	0.5	0.0	0.0	.45	.074	.019
1969	7.3	702.5	539.5	76.8	163.0	23.2	1.0	0.1	0.0	0.0	.27	.040	.009
1970	6.4	720.0	640.0	88.9	80.0	11.1	1.0	0.1	0.0	0.0	.30	.055	.006
1971	6.8	482.0	443.5	92.1	38.5	7.9	0.2	0.4	0.0	0.0	.28	.070	.001

Table 3 (cont'd)

Summary of sulphur dioxide data recorded at Goudreau, Ont. 1961-1971

Year	S lost as SO ₂ 1000 tons	Total sampling time (hrs.)	Zero readings hrs. %		SO ₂ readings hrs. %		Half-hour concs. above				Max. ppm $\frac{1}{2}$ -hr.	Av. ppm for	
							.25 ppm		.50 ppm			SO ₂ periods only	total period
- July -													
1961	9.5	722.0	579.5	80.3	142.5	19.7	16.5	2.3	0.0	0.0	0.48	.116	.023
1962	7.2	715.5	570.0	79.7	145.5	20.3	2.5	0.4	0.0	0.0	0.35	.070	.014
1963	6.2	664.0	547.0	82.4	117.0	17.6	2.0	0.3	0.0	0.0	0.31	.059	.010
1964	6.8	691.5	561.5	81.2	130.0	18.8	2.5	0.4	0.0	0.0	0.35	.063	.012
1965	7.7	707.5	581.5	82.2	126.0	17.8	1.5	0.2	0.0	0.0	0.39	.060	.011
1966	8.0	744.0	498.5	67.0	245.5	33.0	13.0	1.8	3.5	0.5	0.62	.083	.027
1967	5.6	691.5	438.0	63.3	253.5	36.7	10.5	1.5	0.0	0.0	0.39	.075	.028
1968	7.8	710.5	455.5	64.1	255.0	35.9	11.5	1.6	0.0	0.0	0.49	.074	.027
1969	6.6	742.5	579.5	78.1	163.0	21.9	3.0	0.4	0.0	0.0	0.35	.059	.013
*1970	-	711.0	683.5	96.1	27.5	3.9	1.0	0.1	0.0	0.0	0.27	.072	.003
1971	6.9	732.5	557.0	76.1	175.5	23.9	4.5	0.1	0.0	0.0	0.42	.060	.020
- August -													
1961	7.9	743.5	623.0	83.6	120.5	16.2	5.5	0.7	0.0	0.0	0.39	.079	.013
1962	7.0	660.5	512.0	77.5	148.5	22.5	3.0	0.4	0.0	0.0	0.34	.065	.015
1963	7.0	740.5	603.5	81.5	137.0	18.5	1.0	0.1	0.0	0.0	0.33	.058	.011
1964	5.2	681.5	624.0	91.6	57.5	8.4	0.0	0.0	0.0	0.0	0.21	.049	.004
1965	8.2	744.0	639.5	86.0	104.5	14.0	3.5	0.5	0.0	0.0	0.34	.083	.012
1966	7.6	732.5	652.0	89.0	80.5	11.0	0.0	0.0	0.0	0.0	0.22	.048	.005
1967	6.6	744.0	570.0	76.6	174.0	23.4	8.0	1.1	0.5	0.1	0.66	.082	.019
1968	7.4	744.0	595.0	80.0	149.0	20.0	5.0	0.7	1.0	0.1	1.13	.077	.015
*1969	0.4	744.0	741.0	99.6	3.0	0.4	0.0	0.0	0.0	0.0	0.16	.102	.001
1970	5.6	454.0	429.0	94.5	25.0	5.5	0.0	0.0	0.0	0.0	0.11	.037	.002
1971	6.9	724.5	641.0	88.4	83.5	11.6	2.5	0.0	0.0	0.0	0.48	.080	.010

** Plant shutdown from July 4th, 1970 to August 3rd, 1970

* 1969 Shutdown from August 2nd, to November 10th.

Table 3 (cont'd)

Summary of sulphur dioxide data recorded at Goudreau, Ont. 1961-1971

Year	S lost as SO2 1000 tons	Total sampling time (hrs.)	Zero		SO2		Half-hour concs. above				Max. ppm $\frac{1}{2}$ -hr.	Av. ppm for	
			readings hrs.	%	readings hrs.	%	.25 ppm		.50 ppm			SO2 periods only	Total period
							hrs.	%	hrs.	%			
- September -													
1961		563.0	503.5	89.4	59.5	10.6	1.0	0.2	0.0	0.0	0.34	.063	.007
1962		720.0	652.5	90.6	67.5	9.4	3.0	0.4	0.5	0.1	0.80	.078	.007
1963		581.5	460.0	79.1	121.5	20.9	8.5	1.5	0.5	0.1	0.72	.088	.018
1964		632.0	579.5	91.7	52.5	8.3	0.0	0.0	0.0	0.0	0.14	.044	.004
1965		720.0	666.0	92.5	54.0	7.5	0.5	0.1	0.0	0.0	0.27	.048	.004
1966		720.0	660.0	91.7	60.0	8.3	0.0	0.0	0.0	0.0	0.21	.050	.004
1967		674.5	561.0	83.2	113.5	16.5	6.5	1.0	0.5	0.1	0.53	.091	.015
1968		720.0	661.0	91.8	59.0	8.2	0.5	0.0	0.0	0.0	0.31	.051	.004
*1969		720.0	720.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	.000	.000
1970		678.5	649.0	95.6	29.5	4.4	0.5	0.0	0.0	0.0	0.31	.049	.002
1971		343.0	325.5	94.9	17.5	5.1	0.0	0.0	0.0	0.0	0.19	.040	.002
- October -													
1961		286.0	260.5	91.1	25.5	8.9	0.5	0.2	0.0	0.0	0.32	.058	.005
1962		276.5	233.0	84.6	42.5	15.4	2.5	0.9	0.5	0.2	0.52	.080	.012
1963		321.5	234.5	72.9	87.0	27.1	8.5	2.6	0.5	0.2	0.52	.110	.030
1964		326.0	317.5	97.4	08.5	2.6	0.0	0.0	0.0	0.0	0.13	.048	.001
1965		322.0	312.0	96.9	10.0	3.1	0.0	0.0	0.0	0.0	0.13	.038	.001
1966		384.0	374.0	97.4	10.0	2.6	0.0	0.0	0.0	0.0	0.14	.055	.001
1967		388.0	330.0	85.0	58.0	15.0	0.0	0.0	0.0	0.0	0.16	.044	.006
1968		396.0	339.0	85.6	57.0	14.4	1.5	0.4	0.0	0.0	0.31	.056	.008
*1969		516.5	516.5	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	.000	.000
1970		468.0	439.0	93.8	29.0	6.2	0.0	0.0	0.0	0.0	0.16	.034	.002
1971		225.0	220.0	97.7	5.0	2.3	0.0	0.0	0.0	0.0	0.13	.040	.001

* Plant shutdown from August 2nd, to November 10th, 1969

Table 3 (cont'd)

Summary of sulphur dioxide data recorded at Goudreau, Ont. 1961-1971*

Year	S lost as SO2 1000 tons	Total sampling time (hrs.)	Zero readings		SO2 readings		Half-hour concs. above				Max. ppm $\frac{1}{2}$ hr.	Av. ppm for	
			hrs.	%	hrs.	%	.25 ppm		.50 ppm			SO2 periods only	Total period
							hrs.	%	hrs.	%			
- Season -													
1961	36.5**	2671.5	2214.0	82.9	457.5	17.1	30.0	1.1	0.0	0.0	0.48	.094	.016
1962	28.7	3128.5	2556.5	81.7	572.0	18.3	14.0	0.4	1.0	0.1	0.80	.072	.013
1963	28.8	2875.5	2256.0	78.5	619.5	21.5	20.0	0.7	1.0	0.1	0.72	.067	.014
1964	26.1	3068.0	2529.5	85.7	438.5	14.3	12.0	0.4	1.5	0.1	0.61	.065	.009
1965	32.2	3281.5	2785.0	84.9	496.5	15.1	12.5	0.4	1.0	0.1	0.60	.071	.011
1966	28.8	3442.5	2813.0	81.7	629.5	18.3	20.0	0.6	3.5	0.1	0.62	.070	.013
1967	25.2	3493.5	2660.5	76.2	833.0	23.8	31.0	0.9	1.0	0.03	0.66	.074	.018
1968	30.8	3593.5	2870.0	79.9	723.5	20.1	26.0	0.7	1.5	0.04	1.13	.072	.014
1969	18.5	3506.0	3162.5	90.2	343.5	9.8	4.0	0.0	0.0	0.00	0.35	.050	.005
1970	18.1	3189.5	2990.5	93.8	199.0	6.2	2.5	0.8	0.0	0.00	0.31	.050	.003
1971		2507.0	2187.0	87.3	320.0	12.7	9.0	0.3	0.0	0.00	0.48	.071	.009

* SO₂ Autometer
Operative Periods

1961 June 15 - October 16
1962 May 24 - October 12
1963 May 31 - October 14
1964 May 27 - October 14
1965 May 26 - October 14

1966 May 25 - October 16
1967 May 17 - October 17
1968 May 15 - October 17
1969 May 28 - October 22
1970 May 20 - October 20
1971 June 10 - October 14

** May 16 - September 15

' Plant shutdown from August 2nd, to November 10th, 1969

' Plant shutdown from July 4th, to August 3rd, 1970

Table 4

Percentage frequencies of wind directions at Wawa**

Wind	May		June		July		August		September		Season (May - Sept.)	
	Mean* %	1971 %	Mean* %	1971 %	Mean* %	1971 %	Mean* %	1971 %	Mean* %	1971 %	Mean* %	1971 %
N	15.0	10.0	11.5	12.2	12.5	7.9	14.6	9.9	15.4	14.6	14.0	11.0
NE	12.2	36.7	2.4	22.8	6.4	7.0	9.9	19.6	12.3	11.4	11.1	18.2
E	2.7	5.0	2.2	1.0	1.0	0.7	1.9	1.1	1.8	0.6	1.8	1.4
SE	3.9	0.4	2.4	1.6	1.9	0.3	3.1	0.8	3.3	3.2	3.2	1.3
S	13.9	9.8	16.5	9.2	19.8	6.9	12.4	5.2	11.0	13.6	14.5	8.8
SW	7.1	34.2	32.1	36.4	34.3	57.5	31.9	37.9	28.1	22.1	30.4	38.0
W	7.5	2.5	4.5	9.2	0.4	8.7	3.9	10.1	6.8	20.3	5.1	10.7
NW	5.5	1.4	3.6	2.2	4.7	2.7	5.8	1.7	8.0	2.2	5.9	2.1
C	9.0	0.0	9.4	0.0	7.9	0.0	8.6	0.0	11.0	0.0	8.6	0.0
Inop	3.7	0.0	5.1	5.4	6.5	8.3	7.7	13.7	3.4	12.0	5.1	8.5
Prevailing wind	S	NE	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW

* 1962 - 1969 inclusive

** Meteorological data supplied by Algoma Ore Properties Division The Algoma Steel Corporation, Limited

Table 5 Summary of recorder data during the hours between sunrise and sunset at Goudreau, during 1971

Month	No. of days recorder was operating	No. of days with SO ₂	No. of days when av. concs. exceeded min. limits*	Max. av. conc. for				Max. Intensity*
				1 hr. ppm	2 hr. ppm	4 hr. ppm	8 hr. ppm	
June	21	11	0	.28	.25	.19	.10	54
July	31	22	0	.38	.33	.21	.11	60
August	31	17	0	.36	.23	.16	.12	48
September	30	7	0	.18	.13	.07	.07	28
October	20	5	0	.12	.07	.03	.01	13
Total	133	62	0	.38	.33	.21	.12	60

* Approximate threshold limits for vegetation injury i.e., .95 ppm for 1 hour or .55 ppm for 2 hours or .35 ppm for 4 hours or .25 ppm for 8 hours or an intensity of 100.

Table 6 Monthly maximum intensities recorded at Goudreau from 1961-1971

Year	Month			
	June (Int.)	July (Int.)	August (Int.)	September (Int.)
1961	69	100	51	12
1962	60	40	46	32
1963	29	40	44	48
1964	73	35	20	16
1965	51	53	37	20
1966	44	75	28	24
1967	43	64	56	83
1968	56	66	54	34
1969	20	40	24	0
1970	28	43	13	37
1971	54	60	48	28
Maximum	73	100	56	83

Table 7

Summary of the Changes in "Crown Condition" of the Trees
and Shrubs on the Wawa **Vegetation** Plots from 1969 to 1970
and from 1970 to 1971

<u>Plot No.</u>	<u>Location</u>	<u>Date</u>	No. of Trees or Shrubs where the Crown Condition has		
			<u>Improved</u>	<u>Declined</u>	<u>Remained Unchanged</u>
2	10 m. NE	1969 to 1970	2	7	11
		1970 to 1971	4	6	9 (& 1 dead)
3	12 m. NE	1969 to 1970	0	5	15
		1970 to 1971	9	2	8 (& 1 removed by beaver)
4	16 m. NE	1969 to 1970	0	9	11
		1970 to 1971	5	1	14
5	19 m. NE	1969 to 1970	1	5	14
		1970 to 1971	6	0	14
6	22 m. NE	1969 to 1970	5	3	12
		1970 to 1971	4	1	15
7	24 m. NE	1969 to 1970	2	6	12
		1970 to 1971	4	0	16
1 (Control)	35 m. NW	1969 to 1970	0	4	16
		1970 to 1971	11	2	7
8 (Control)	38 m. NE	1969 to 1970	2	4	14
		1970 to 1971	4	5	11

Table 2

Summary of the Ground Flora Populations in the Grids adjacent to
the Wawa Vegetation Plots in 1969, 1970, and 1971

Plot No.	Location	Grid No.		Trees			Shrubs			Herbaceous plants			Grasses, Sedges, Mosses, Lichens.		
			Year	'69	'70	'71	'69	'70	'71	'69	'70	'71	'69	'70	'71
2	10 m. NE	1	No. of Species	1	1	1	4	4	4	6	8	9	-	-	-
			No. of Individ.	12	8	5	7	9	6	287	338	407	-	-	-
			No. of Clumps	-	-	-	19	27	22	1	5	4	-	33	29
		2	No. of Species	2	2	2	6	6	6	7	9	9	-	-	-
			No. of Individ.	2	2	2	7	7	11	166	264	265	3	2	2
			No. of Clumps	-	-	-	-	-	-	2	4	2	8	12	20
3	12 m. NE	1	No. of Species	1	1	1	2	2	2	5	5	5	-	-	-
			No. of Individ.	11	8	4	2	1	-	221	371	333	-	-	-
			No. of Clumps	-	-	-	24	42	28	7	40	44	4	10	9
		2	No. of Species	1	1	1	4	4	4	6	6	6	-	-	-
			No. of Individ.	1	2	1	4	9	7	226	356	376	-	-	-
			No. of Clumps	-	-	-	23	29	28	12	12	8	14	15	18
4	16 m. NE	1	No. of Species	2	2	1	5	5	5	6	7	7	-	-	-
			No. of Individ.	7	3	4	17	24	22	186	250	231	-	-	-
			No. of Clumps	-	-	-	7	11	7	8	40	21	29	74	48
		2	No. of Species	3	3	3	2	3	3	3	3	5	-	-	-
			No. of Individ.	4	3	3	1	2	2	223	258	168	-	-	-
			No. of Clumps	-	-	-	12	23	25	-	-	1	-	-	2

Table 8 (cont'd) Summary of the Ground Flora Populations in the Grids adjacent to the Wawa Vegetation Plots in 1969, 1970 and 1971

Plot No.	Location	Grid No.		Trees			Shrubs			Herbaceous plants			Grasses, Sedges, Mosses, Lichens		
			Year	'69	'70	'71	'69	'70	'71	'69	'70	'71	'69	'70	'71
5	19 m. NE	1	No. of Species	1	1	-	4	4	4	4	5	5	-	-	-
			No. of Individ.	1	1	-	24	31	26	383	692	436	-	-	-
			No. of Clumps	-	-	-	76	54	51	-	-	-	1	8	10
		2	No. of Species	3	3	3	2	2	3	3	6	6	-	-	-
			No. of Individ.	38	37	18	3	2	2	54	328	253	-	-	-
			No. of Clumps	-	-	-	96	98	84	2	2	2	16	47	36
6	22 m. NE	1	No. of Species	3	3	3	3	3	3	6	6	6	-	-	-
			No. of Individ.	15	15	8	7	5	5	62	103	108	39	24	18 (ferns)
			No. of Clumps	-	-	-	31	48	48	5	9	6	15	22	25
		2	No. of Species	2	2	2	4	4	4	5	5	5	-	-	-
			No. of Individ.	3	3	2	3	3	1	66	152	78	-	-	-
			No. of Clumps	-	-	-	8	11	23	22	14	41	11	10	19
7	24 m. NE	1	No. of Species	1	-	-	3	4	3	4	5	5	-	-	-
			No. of Individ.	2	-	-	2	3	1	42	101	87	-	-	-
			No. of Clumps	-	-	-	Vaccinium throughout			-	-	-	2	2	4
		2	No. of Species	-	-	-	4	4	4	3	4	5	-	-	-
			No. of Individ.	-	-	-	6	10	11	49	77	74	-	-	-
			No. of Clumps	-	-	-	13	16	16	-	-	-	7	4	5

Table 8 (cont'd) Summary of the Ground Flora Populations in the Grids adjacent to
the Wawa Vegetation Plots in 1969, 1970, and 1971

Plot No.	Location	Grid No.		Trees			Shrubs			Herbaceous plants			Grasses, Sedges, Mosses, Lichens		
			Year	'69	'70	'71	'69	'70	'71	'69	'70	'71	'69	'70	'71
1 (control)	35 m. NW	1	No. of Species	2	2	3	1	2	2	3	3	3	-	-	-
			No. of Individ.	10	10	9	1	2	1	117	159	148	-	-	-
			No. of Clumps	-	-	-	-	-	-	-	-	-	40	43	37
		2	No. of Species	2	2	2	1	1	1	6	7	7	-	-	-
			No. of Individ.	10	8	5	-	-	-	147	148	123	16	12	13 (ferns)
			No. of Clumps	-	-	-	18	13	11	1	2	1	11	12	13
8 (Control)	38 m. NE	1	No. of Species	2	2	2	2	2	2	7	7	6	-	-	-
			No. of Individ.	13	10	10	10	7	8	340	377	373	-	-	-
			No. of Clumps	-	-	-	2	2	2	1	-	-	3	7	7
		2	No. of Species	4	4	4	3	3	3	7	7	7	-	-	-
			No. of Individ.	29	17	14	6	7	7	193	236	236	-	-	-
			No. of Clumps	-	-	-	1	2	2	-	-	-	10	32	22

Table 9

Mean Values of Sulphur Recorded from 1961-1970 in the Original
Wawa Lead Peroxide Candle Survey Expressed as $\text{mgm SO}_3/100 \text{ cm}^2/\text{day}$

<u>Station & Location</u>	<u>May</u>	<u>June</u>	<u>July</u>	<u>August</u>	<u>September</u>	<u>Mean (J.J.A.)[*]</u>
Goetz Lake (Parks Lake) 10 m. NE	.88	1.82	1.35	1.10	.90	1.42
Magpie River 14 m. NE	.79	.90	.63	.38	.41	.63
Goudreau 21.6 m. NE	.47	.76	.46	.36	.45	.52
Herman Lake 24 m. NE	.49	.75	.46	.44	.37	.55
Cawdron Lake 30 m. NE	.23	.38	.40	.22	.23	.33
Localsh 34 m. NE	.28	.39	.30	.23	.39	.30

*J.J.A. - June, July, August

Table 10

Values of Sulphur Recorded in 1970 on the Lead Peroxide Candles
at the Vegetation Plots in the Wawa Area expressed as
mgm SO₃/100 cm²/day

Plot No.	Location	June	*July	August	Average of June and August
2	10 m. NE	1.31	-	.74	1.03
3	12 m. NE	.89	-	.34	.61
4	16 m. NE	.57	.15	-	.57
5	19 m. NE	.28	-	.23	.25
6	22 m. NE	.35	.12	-	.35
7	24 m. NE	.25	.09	-	.25
1 (Control)	35 m. NW	.03	.05	.05	.04
8 (Control)	38 m. NE	.24	.07	.04	.08

* Sinter Plant shut down from July 4 to August 3.

- Data invalid

Table 11

Values of Sulphur Recorded in 1971 on the Lead Peroxide
Candles at the Vegetation Plots in the Wawa area
expressed as $\text{mgm SO}_3/100 \text{ cm}^2/\text{day}$

Plot No.	Location	June	July	August	Mean
2	10 m. NE	1.29	2.47	.67	1.47
3	12 m. NE	.95	1.25	.46	.88
4	16 m. NE	.42	.46	.20	.36
5	19 m. NE	.42	.55	.20	.39
6	22 m. NE	.20	.41	.19	.26
7	24 m. NE	.23	.25	.13	.20
1 (Control)	35 m. NW	.11	.01	.01	.04
8 (Control)	38 m. NE	.12	.16	.08	.12

Table 12

Concentrations of Various Chemical Elements in Vegetation
collected at the Eight Study Plots in the Wawa
Area in 1970 (Average of four monthly collections)

Species: Trembling Aspen

<u>Plot No.</u>	<u>Location</u>	<u>Elements</u>					
		<u>F</u> ppm	<u>ToS</u> %	<u>SO₄-S</u> %	<u>As</u> ppm	<u>Fe</u> ppm	<u>Zn</u> ppm
2	10 m. NE	2	<u>.31*</u>	<u>.29</u>	<u>22.8</u>	89	380
3	12 m. NE	-	-	-	-	-	-
4	16 m. NE	7	<u>.22</u>	<u>.25</u>	<u>5.8</u>	56	300
5	19 m. NE	-	-	-	-	-	-
6	22 m. NE	4	<u>.25</u>	<u>.21</u>	<u>3.3</u>	53	264
7	24 m. NE	4	<u>.22</u>	<u>.20</u>	<u>5.8</u>	60	307
8	38 m. NE	8	<u>.21</u>	<u>.17</u>	<u>1.9</u>	57	190
(Control)							
1	35 m. NW	4	<u>.21</u>	<u>.17</u>	0.7	51	151
(Control)							

Species: White Birch

<u>Plot No.</u>	<u>Location</u>	<u>F</u> ppm	<u>ToS</u> %	<u>SO₄-S</u> %	<u>As</u> ppm	<u>Fe</u> ppm	<u>Zn</u> ppm
2	10 m. NE	5	<u>.25</u>	<u>.25</u>	<u>19.6</u>	51	226
3	12 m. NE	6	<u>.24</u>	<u>.18</u>	<u>14.1</u>	65	240
4	16 m. NE	3	<u>.28</u>	<u>.18</u>	<u>8.0</u>	38	252
5	19 m. NE	13	<u>.24</u>	<u>.20</u>	<u>9.9</u>	64	188
6	22 m. NE	4	<u>.18</u>	<u>.15</u>	<u>7.5</u>	55	198
7	24 m. NE	7	<u>.19</u>	<u>.17</u>	<u>6.6</u>	64	152
8							
(Control)	38 m. NE	4	<u>.16</u>	<u>.14</u>	2.6	44	228
1	35 m. NW	6	<u>.15</u>	<u>.08</u>	0.8	47	88
(Control)							

* Underlined values are markedly higher than control values

Table 12 (cont'd)

Concentrations of Various Chemical Elements in Vegetation
collected at the Eight Study Plots in the Wawa
Area in 1970 (Average of four monthly collections)

Species: Mountain Maple

Elements

<u>Plot No.</u>	<u>Location</u>	F ppm	ToS %	SO ₄ -S %	As ppm	Fe ppm	Zn ppm
2	10 m. NE	<u>13**</u>	<u>.24</u>	<u>.22</u>	<u>18.2</u>	85	37
3	12 m. NE	<u>17</u>	<u>.39</u>	<u>.23</u>	<u>7.8</u>	59	43
4	16 m. NE	5	.17	.16	<u>5.3</u>	52	40
5	19 m. NE	-	-	-	-	-	-
6	22 m. NE	3	<u>.24</u>	<u>.20</u>	3.7	46	27
7	24 m. NE	8	<u>.16</u>	<u>.18</u>	3.7	46	37
*8	38 m. NE	4	.19	.17	1.9	58	45
*1	35 m. NE	4	.20	.10	0.6	69	33

Species: Showy Mountain Ash

<u>Plot No.</u>	<u>Location</u>	F ppm	ToS %	SO ₄ -S %	As ppm	Fe ppm	Zn ppm
2	10 m. NE	5	<u>.21</u>	<u>.22</u>	<u>15.0</u>	63	28
3	12 m. NE	8	<u>.23</u>	<u>.24</u>	<u>11.3</u>	39	25
4	16 m. NE	4	<u>.20</u>	<u>.18</u>	<u>6.6</u>	31	28
5	19 m. NE	11	<u>.18</u>	<u>.17</u>	<u>9.4</u>	31	24
6	22 m. NE	5	.16	.08	3.5	-	18
7	24 m. NE	7	.14	.15	4.5	40	24
*8	38 m. NE	5	.13	.12	1.4	37	27
*1	35 m. NW	8	.14	.11	.6	43	31

* Plots 1 and 8 - control plots

** Underlined values are markedly higher than control values

Table 12 (cont'd)

Concentrations of Various Chemical Elements in Vegetation and
Soil collected at the Eight Study Plots in the Wawa
Area in 1970 (Average of four monthly collections)

<u>Species:</u> <u>Forage</u>		<u>Elements</u>					
<u>Plot No.</u>	<u>Location</u>	F ppm	ToS %	SO ₄ -S %	As ppm	Fe ppm	Zn ppm
2	10 m. NE	2	.18	.22	<u>8.4</u> ***	62	37
3	12 m. NE	3	.16	.17	<u>4.8</u>	49	40
4	16 m. NE	3	.21	.21	<u>5.6</u>	40	37
5	19 m. NE	7	.15	.14	<u>5.1</u>	48	50
6	22 m. NE	3	.17	.19	2.2	48	37
7	24 m. NE	3	.16	.20	3.0	46	39
*8	38 m. NE	4	.16	.16	0.9	72	35
*1	35 M. NW	3	.21	.20	0.5	53	50

<u>Soil**</u>							
<u>Plot No.</u>	<u>Location</u>	F ppm	ToS %	SO ₄ -S meq.	As ppm	Fe %	Zn ppm
2	10 m. NE	120	<u>.047</u>	<u>.31</u>	<u>56.7</u>	1.92	57
3	12 m. NE	80	<u>.048</u>	<u>.60</u>	<u>24.4</u>	1.92	23
4	16 m. NE	160	<u>.034</u>	<u>.39</u>	<u>9.6</u>	.67	18
5	19 m. NE	100	.03	<u>.33</u>	<u>19.6</u>	2.20	36
6	22 m. NE	100	.03	.21	6.4	1.96	55
7	24 m. NE	120	.02	.20	4.1	1.36	21
*8	38 m. NE	100	.02	.20	2.1	.85	24
*1	35 m. NW	60	.014	.20	.7	.08	3

* Plots 1 and 8 - control plots

** Average of two monthly collections

*** Underlined values are markedly higher than control values

Table 13

Summary of Analysis of Variance (F-Values)
for different Chemicals in the Wawa Area in 1970

<u>Chemical</u>	Total Sulphur	Sulphate- Sulphur	Arsenic	Fluoride	Iron	Zinc
<u>Sources of Variation</u>						
Species	15.56**	6.24**	12.03**	0.35	14.15**	110.35**
Stations	9.35**	13.39**	60.72**	2.47*	6.27**	4.36**
* Significant at 5% level ** Significant at 1% level						

Table 14

The Correlation Coefficients and Regression Equations for the
Relationship between Distance from the Source and the Results
of the Vegetation Chemical Analysis - Wawa 1970

<u>Chemicals</u>	<u>Regression Equation</u>	<u>Correlations Coefficient</u>
Total Sulphur	$Y = 0.26 - 0.00 X$	- 0.81*
Sulphate-Sulphur	$Y = 0.24 - 0.00 X$	- 0.87*
Arsenic	$Y = 15.30 - 0.41 X$	- 0.83*
Fluoride	$Y = 6.92 - 0.04 X$	- 0.22
Iron	$Y = 58.26 - 0.27 X$	- 0.36
Zinc	$Y = 108.62 - 0.03 X$	- 0.01

Y - Chemical Concentration

X - Distance from source (miles)

* - Significant at 5% level

Table 15

The Correlation Coefficient and Regression Equation
of the Air Candle Sulphation Rate and Total Sulphur
and Sulphate-Sulphur Concentration in Vegetation Sampling
WAWA 1970

Plot No.	Location	Average Sulphation rate mgm SO ₃ /100 cm ² /day	No. of Species collected	Mean and Standard Error of Total Sulphur (%)	Mean and Standard Error of Sulphate-Sulphur (%)
2	10 m. NE	1.03	5	0.240 $\pm$ 0.010	0.239 $\pm$ 0.014
3	12 m. NE	.61	4	0.249 $\pm$ 0.026	0.205 $\pm$ 0.010
4	16 m. NE	.57	5	0.216 $\pm$ 0.014	0.196 $\pm$ 0.010
5	19 m. NE	.25	4	0.188 $\pm$ 0.017	0.169 $\pm$ 0.009
6	22 m. NE	.35	7	0.221 $\pm$ 0.014	0.184 $\pm$ 0.010
7	24 m. NE	.25	5	0.174 $\pm$ 0.014	0.181 $\pm$ 0.009
8	38 m. NE	.08	5	0.173 $\pm$ 0.017	0.150 $\pm$ 0.008
1	35 m. NW	.04	5	0.182 $\pm$ 0.017	0.132 $\pm$ 0.010

Total Sulphur

Correlation Coefficient $r = 0.84^*$
Regression Equation $Y = 0.08 X + 0.17$

Sulphate - Sulphur

Correlation Coefficient $r = 0.97^{**}$
Regression Equation $Y = 0.10 X + 0.14$

* Significant at 5% level

** Significant at 1% level

Plots 1 and 8 are control plots



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[illegible]